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Selection Response and Genetic Variability for Yield and its Component Traits of Rice (*Oryza sativa* L.)

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A B S T R A C T

Cross - I exhibited high h^2 coupled with moderate genetic advance as per cent of mean for Tw in all selection methods as well as different methods and date of sowing except in HY selection method on Ist date TP followed by LY selection methods on Ist date DS; and MTL selection methods on 2nd date TP indicating the preponderance of additive gene action as well as non-additive gene action. Cross – II and Cross – III were obtained highest average selection response for all the studied traits in HY followed by LY selection method. Among different methods of selection HY followed by LY selection method may be effective in early segregating generation for Cross – II as well as Cross – III whereas for Cross – I; LY followed by HY selection method may be more effective. It might be probable that delaying selection reduces the frequency of high yielding genotypes resulting in a greater frequency of low yielding genotypes.

Introduction

Rice (*Oryza sativa* L.) is the staple food for around 2.5 billion world's population which is about 60% of the total population and may escalate to 4.6 billion by the year 2050; especially for most of the people of South-East Asia. Among the rice growing countries in the world, India has the largest area under rice crop and ranks second in production next to China. It plays vital role in the national food grain supply. It accounts for about 43% of food grain production in the country. Rice is grown in three seasons in India, where *Kharif* season accounts for 88% production while *Rabi* contributes only 12% production. Rice is the single most important food crop in India and occupies 44.6 m ha under rice cultivation Meera *et al.*, (2014). The population growth in most of the Asian countries, except China, continues to be around 2 percent per year. Hence it is very pertinent to critically consider whether the rice production can be further increased to keep pace with population growth. With the current green revolution

technologies it is estimated that by 2020 at least 115-120 million tons of milled rice is to be produced in India to maintain the present level of self-sufficiency. The total production could be enhanced either by making horizontal expansion in area, which is not possible owing to high population growth, so none of the option left other than vertical expansion, which could be done opting a suitable breeding method.

The early generation testing is one of the best option to reduce the amount of material to be handled in the segregating generations and at the same time retain the good recombinant lines for the traits under improvement. It is also enhanced by selection response which maximises either by selecting the best genotype available in the population or by increasing the rigour of selection. A very rigorous selection may not be desirable as it can eliminate some promising genotypes. Whan *et al.,* (1982) suggested that selection for grain yield in early generation need to be done at many sites simultaneously at an early growth stage. Grain yield is a complex character and is the result of interaction of many variables due to different gene association that might exist in different population and might result in quite different relationships. It is also largely influenced by environment. Further genotype and environmental interaction reduces the effectiveness of early generation selection (Whan *et al.,* (1981). Large environmental differences may lead to failure of parental yield to be indicative of the yield of progeny. The present investigation is aimed to collect the information on effectiveness of the selection in the improvement programme based on the performance of individual groups of three crosses selection from F_2 generation, keeping yield/plant, no. of grain /panicle, thousand grain weight, plant height, and panicle/plant with the following objectives.

Validation of early generation selection

Assessing effective method of early generation selection.

Materials and Methods

The experimental material consisted of three crosses viz; BG102/BPT5204, BG102/Naveen and BG102/ Reshmi (F_1) Commercial Pvt. hybrid (Victory seeds) of rice (*Oryza sativa* L.). Each of the crosses represented a separate experiment which were obtained from Rice Project, Department of Plant Breeding and Genetics, Birsa Agricultural University, Ranchi, Jharkhand. All the materials come under single cross, except, BG102/ Reshmi (F_1) Commercial Pvt. hybrid (Victory seeds) which is a three way cross. The F_2 materials were grown in nursery on 6th June, 2013. Thirty (30) days old seedlings were transplanted in the puddled field. Out of total 5000 F_2 established population, 1000 F_2 were tagged randomly after flowering of each cross viz; BG102/BPT5204, BG102/Naveen and BG102/ Reshmi (F_1) Commercial Pvt. Hybrid (Victory seeds) respectively and represented as Cross- I, Cross- II and Cross- III. The data recording and harvesting of each plants were done separately so that these F_2 plants be categorized and selected. On the basis of these data 50 plants were selected in each groups viz., high yielder (HY), low yielder (LY), multi trait limit (MTL) and random plant selection (RPS). Each group comprising 50 plants but in MTL having only 48, 49 and 42 plants in each cross viz; Cross- I, Cross- II and Cross- III respectively. High and low yielder plants were selected on the basis of their high and low yield potential however, in MTL group optimum plants were selected by fixing certain traits range viz; PH (70-110 cm), PPP (5-25), PL (18-35 cm), GPP (80-250) and test wt. (100 seed, 1.9-3.0 g) but in RPS group plant was selected on random basis. These F_2 selected plants were grown during *kharif*, 2014 in RBD with two replication and two

methods of sowing, such as, direct seeded and transplanted at twenty days interval; each plot measuring 2.7 x 0.4 meter size. The row to row distance was kept at 20cm while plant to plant distance was maintained at 15cm. A fertilizer dose of 80: 40: 30 N:P:K Kg/ ha was applied in two parts 40 kg of N, all phosphate and potash were applied as a basal and the remaining 40 kg N was applied as top dressing in two split doses. The analysis of variance was carried out separately for each trait as per formula suggested by Panse and Sukhatme (1967), phenotypic and genotypic coefficient of variation by Burton (1952), heritability (Broad sense) and genetic advance as per cent of mean were estimated by the formula as suggested by Johanson *et al.,* (1955). Standardized selection differential, response to selection and realized heritability were estimated as per Falconer (1989).

Results and Discussion

The results obtained with respect to genetic variability of different traits of F_3 generations are given in the (Table 1, 2 and 3). Knowledge on nature and magnitude of genotypic and phenotypic variability present in any crop species plays an important role in formulating successful breeding programmes (Allard, 1960). Sivasubramanian and Menon (1973) also highlighted the importance of variability in early segregating generations and suggested that magnitude of genotypic coefficient of variability and phenotypic coefficient of variability should be given importance. Jennings *et al.,* (1979) suggested that crosses which will realise early homozygosity are ideally suited for further breeding work.

In general PCV was bit higher than GCV in all crosses which indicates additive effect of environment on the expression of the trait. Similar finding have been reported earlier by Mohan and Chauhan (2011), Praveen *et al.,* (2010), Chakraborty and Chakraborty (2010) and Gala *et al.,* (2016).

In $50F_3$ progenies of Cross - I, high h^2 coupled with moderate genetic advance as per cent of mean has been recorded for Tw in all selection methods as well as different methods and date of sowing except in HY group on I^{st} date TP followed by LY selection methods on I^{st} date DS; and MTL selection methods on 2^{nd} date TP, indicating the preponderance of additive gene action as well as non-additive gene action. For trait GPP recorded high h^2 coupled with high GA as per cent of mean in I^{st} and 2^{nd} date of DS as well as TP respectively under HY selection methods whereas high GA along with moderate h^2 was obtained in both date of sowing under same selection method indicating the preponderance of additive gene action. Similar finding earlier have been reported by Singh *et al.,* (2013), Dutta *et al.,* (2013), Rajendra *et al.,* (2013), Tuhina *et al.,* (2015) and Lingaiah (2015), whereas for most of characters have been recorded high h^2 coupled with low to moderate genetic advance as per cent of mean in HY and LY selection methods which is might be due to preponderance of additive and non- additive gene action. Similar finding earlier has been reported by Chakraborty and Chakraborty (2010) and Sanghera *et al.,* (2013).

In Cross – II of $50F_3$ progenies high h^2 coupled with high GA as per cent of mean has been recorded for Tw in LY group of I^{st} date TP and 2^{nd} date TP along with MTL and RPS.GYP plant had also exhibited high h^2 coupled with high genetic advance as per cent of mean in all most all the selection methods except in HY group and I^{st} date DS and TP whereas in Cross-I II; for traits viz; DFF, PH, PPP, GPP, GYP plant and GYP plot were exhibited high h^2 coupled with high GA as per cent of mean in MTL and RPS selection methods as well as both dates of Sivasubramanian and Menon (1973) planting.

Table.1 Genetic parameters of 50 F_3 progenies selected from F_2 population Cross- I (BG102/BPT5204) based on different selection indices and grown under different crop ecology

Characters	Genetic parameters	I st method of selection (HY)				2nd method of selection (LY)				3rd method of selection (MTL)				4th method of selection (RPS)			
		I st Date		2nd Date		I st Date		2nd Date		I st Date		2nd Date		I st Date		2nd Date	
		DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP
DFF	h^2 (%)	74.59	76.75	42.53	67.64	73.21	22.03	9.60	64.28	65.43	84.12	65.98	84.26	91.13	71.48	78.87	86.18
	GA (%)	12.93	7.31	5.08	5.95	6.72	2.19	1.14	4.94	5.34	6.51	5.38	6.52	8.66	7.18	7.75	8.30
	GCV (%)	4.40	4.05	3.78	3.51	3.83	2.26	1.78	2.99	3.82	3.75	3.94	3.37	5.31	4.52	5.24	4.28
	PCV (%)	5.10	4.62	5.79	4.26	4.48	4.82	5.75	3.72	4.73	4.08	4.85	3.67	5.56	5.35	5.90	4.61
	Mean	72	80	70	89	69	78	68	87	70	80	70	89	70	78	69	88
	Min.	91	97	87	106	83	91	82	101	86	92	82	101	89	96	87	106
	Max.	90	96	87	106	69	77	68	87	85	91	82	101	88	96	86	105
	CD at 0.05	4	4	6	5	4	7	8	4	4	4	3	3	3	5	4	3
	CV %	3	2	6	2	2	4	5	2	3	3	2	1	2	3	3	2
PH (cm)	h^2 (%)	5.35	16.38	10.45	3.73	11.07	18.69	34.66	37.65	15.98	11.21	12.78	27.98	11.34	10.35	70.42	13.12
	GA (%)	0.84	2.20	1.67	0.71	1.52	3.47	5.68	6.09	2.61	1.68	2.23	5.18	2.25	2.07	14.00	2.91
	GCV (%)	1.75	2.63	2.50	1.78	2.22	3.89	4.68	4.82	3.11	2.39	2.97	4.66	3.23	3.11	8.09	3.90
	PCV (%)	7.59	6.50	7.73	9.22	6.69	9.01	7.95	7.85	7.78	7.12	8.32	8.81	9.61	9.69	9.65	10.76
	Mean	122	121	122	122	122	121	122	122	115	115	116	115	121	123	124	124
	Min.	108	106	108	104	109	108	105	109	101	103	102	94	101	96	96	99
	Max.	133	132	135	138	137	160	139	137	129	131	134	135	148	139	147	145
	CD at 0.05	22	14	20	22	16	20	16	15	17	18	16	18	24	23	13	25
	CV %	9	6	8	9	6	8	6	6	7	8	7	7	10	9	5	10
PPP	h^2 (%)	9.93	23.53	25.41	27.26	21.85	41.82	15.61	38.68	27.16	50.69	19.75	27.22	43.97	11.91	53.95	14.88
	GA (%)	3.78	9.56	8.69	12.00	5.64	16.73	5.42	15.24	10.09	35.25	14.98	11.59	20.28	5.84	26.70	7.15
	GCV (%)	5.81	10.87	8.08	9.98	7.38	12.29	6.45	12.54	10.40	24.04	15.57	11.01	13.18	8.97	16.76	8.91
	PCV (%)	18.45	22.41	16.03	19.12	15.79	19.00	16.33	20.17	19.97	33.77	35.06	21.12	19.88	26.01	22.82	23.10
	Mean	12	11	11	12	10	10	10	10	9	9	9	8	10	9	9	9
	Min.	9	8	8	4	7	7	8	7	6	6	7	1	3	6	7	7
	Max.	16	16	15	17	12	14	13	12	13	18	16	12	13	14	15	25
	CD at 0.05	4	4	3	4	3	3	3	3	3	6	4	3	3	4	3	4
	CV %	18	20	14	16	14	14	15	16	17	31	24	18	15	24	15	21
GPP	h^2 (%)	73.41	58.96	69.99	52.46	57.28	41.79	47.27	40.82	50.47	12.35	37.14	49.09	40.39	56.02	47.36	37.68

	GA (%)	39.07	25.91	30.92	21.59	24.72	17.22	20.21	15.90	24.26	6.24	15.43	20.71	18.54	22.30	23.37	16.06
	GCV (%)	22.13	16.38	17.94	14.46	15.85	12.92	14.26	12.27	16.28	8.47	12.08	14.10	14.16	14.46	14.60	12.70
	PCV (%)	25.83	21.33	21.44	19.97	20.94	19.99	20.75	19.20	22.91	24.12	19.82	20.12	22.28	19.32	21.22	20.68
	Mean	81	103	99	88	88	89	90	89	85	86	88	84	89	83	89	89
	Min.	36	54	56	18	50	66	52	50	54	57	59	25	62	47	64	69
	Max.	113	143	132	118	135	131	138	135	141	124	116	110	135	112	133	176
	CD at 0.05	22	28	24	24	25	27	28	26	28	28	39	24	31	21	27	29
	CV %	13	14	12	14	14	15	15	15	16	16	23	14	17	13	15	16
TW(g)	**h^2 (%)**	76.00	84.77	82.59	96.42	95.35	92.00	93.39	89.07	86.38	92.10	88.87	95.94	62.27	86.06	79.19	86.47
	GA (%)	12.20	14.56	13.13	26.33	20.97	19.94	21.24	21.17	15.98	16.76	16.17	27.90	10.01	14.42	12.86	13.07
	GCV (%)	6.79	7.67	7.01	13.01	10.42	10.09	10.66	10.83	8.17	8.30	8.15	13.55	6.15	7.54	7.01	6.82
	PCV (%)	7.79	8.33	7.71	13.25	10.67	10.51	11.04	11.48	8.80	8.65	8.65	13.83	7.79	8.13	7.88	7.33
	Mean	22	21	22	22	21	21	21	21	21	21	21	21.26	22	22	22	21
	Min.	18	18	18	18	17	18	17	18	18	17	18	17.89	19	19	19	19
	Max.	25	25	25	26	27	27	27	27	25	25	25	25.41	25	26	26	24
	CD at 0.05	2	1	1	1	1	1	1	2	1	1	1	1.17	2	1	2	1
	CV %	4	3	3	3	2	3	3	4	3	3	2	2.79	5	3	4	3
GYP Plant (g)	**h^2 (%)**	46.14	28.47	35.74	50.26	50.32	59.74	32.16	25.01	49.89	53.38	31.42	17.23	31.57	29.84	41.84	16.05
	GA (%)	18.45	11.58	14.92	25.29	28.25	25.77	10.73	6.38	45.55	43.06	22.30	6.26	14.67	10.76	28.40	4.60
	GCV (%)	13.18	10.53	12.10	17.31	19.32	16.18	9.18	6.44	30.80	28.14	19.02	7.19	12.67	9.55	21.30	5.56
	PCV (%)	19.40	19.75	20.25	24.42	27.24	20.93	16.18	12.87	43.61	38.51	33.94	17.31	22.55	17.48	32.94	13.89
	Mean	22	21	22	22	21	21	21	21	21	21	21	21.26	22	22	22	21
	Min.	18	18	18	18	17	18	17	18	18	17	18	17.89	19	19	19	19
	Max.	25	25	25	26	27	27	27	27	25	25	25	25.41	25	26	26	24
	CD at 0.05	2	1	1	1	1	1	1	2	1	1	1	1.17	2	1	2	1
	CV %	4	3	3	3	2	3	3	4	3	3	2	2.79	5	3	4	3
GYP Plot (g)	**h^2 (%)**	44.28	35.19	57.01	34.98	19.01	18.99	49.76	19.01	14.13	13.36	16.44	33.57	4.09	12.41	21.24	14.97
	GA (%)	17.23	15.01	29.53	16.42	6.59	7.01	25.07	6.59	4.12	4.17	6.61	12.64	1.37	4.01	12.50	5.65
	GCV (%)	12.57	12.27	18.98	13.47	7.33	7.80	17.25	8.65	5.32	5.53	7.91	10.58	3.29	5.52	13.15	7.09
	PCV (%)	18.89	20.69	25.14	22.77	16.81	17.91	24.45	19.84	14.16	15.13	19.52	18.27	16.28	15.66	28.54	18.32
	Mean	256	241	219	218	243	227	208	243	223	209	186	180	237	223	180	189
	Min.	188	174	146	151	184	168	136	184	169	156	132	120	170	158	123	123
	Max.	355	342	319	319	342	326	303	342	262	249	262	225	310	295	303	261
	CD at 0.05	73	81	72	81	74	74	73	74	59	59	67	54	76	66	92	64
	CV %	14	17	16	18	15	16	17	18	13	14	18	15	16	15	25	17

Table.2 Genetic parameters of 50 F_3 progenies selected from F_2 population Cross- II (BG102/Naveen) based on different selection indices and grown under different crop ecology

Characters	Genetic parameters	I st method of selection (HY)				2nd method of selection (LY)				3rd method of selection (MTL)				4th method of selection (RPS)			
		I st Date		2nd Date		I st Date		2nd Date		I st Date		2nd Date		I st Date		2nd Date	
		DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP
DFF	h^2 (%)	68	64	24.3	77	61.05	65.91	50.17	43.31	3.06	45.02	9.85	95.72	53.34	65.94	32.59	55.04
	GA (%)	4.8	4.3	2.06	4.4	4.28	4.17	3.69	2.65	0.11	1.42	0.45	26.92	2.67	3.18	1.94	2.75
	GCV (%)	2.9	2.6	1.94	2.5	2.68	2.41	2.34	1.99	0.4	1.13	0.83	14.33	2.24	2.09	1.97	1.88
	PCV (%)	3.6	3.2	3.93	2.9	3.43	2.96	3.3	3.03	2.3	1.69	2.66	14.65	3.07	2.58	3.45	2.53
	Mean	75	85	79	90	75	86	79	90	73	76	83	88	73	77	83	88
	Min.	70	80	74	85	72	82	76	87	71	73	82	86	69	72	80	84
	Max.	82	93	86	97	81	91	85	96	76	80	87	91	79	83	90	94
	CD at 0.05	3	3	5	2	3	3	4	4	3	2	4	5	3	3	4	3
	CV %	2	2	3	1	2	2	2	2	2	1	3	3	2	2	3	2
PH (cm)	h^2 (%)	17	16	14.9	10	15.95	12.03	11.02	17.08	10.75	23.14	13.55	60.23	6.53	5.71	14.2	12.15
	GA (%)	2.2	2.1	2	1.1	2.21	1.5	1.46	1.67	1.35	2.88	2.18	20.53	0.75	0.63	1.59	1.12
	GCV (%)	2.6	2.6	2.51	1.6	2.69	2.09	2.13	1.96	1.99	2.9	2.87	13.1	1.42	1.27	2.04	1.55
	PCV (%)	6.2	6.6	6.51	4.9	6.75	6.03	6.44	4.75	6.09	6.03	7.79	16.88	5.57	5.34	5.43	4.46
	Mean	117	117	116	117	115	114	116	117	104	93	92	92	115	115	114	114
	Min.	103	108	107	104	97	102	100	104	98	80	80	85	99	102	105	104
	Max.	130	136	135	129	128	132	131	129	121	105	103	100	125	130	131	126
	CD at 0.05	13	15	15	11	15	14	15	10	13	10	14	19	13	12	12	10
	CV %	6	6	6	5	6	6	6	4	6	5	7	11	5	5	5	4
PPP	h^2 (%)	13	12	20.3	24	10.29	56.15	19.21	36.13	11.93	28.85	11.32	39.68	14.29	29.6	18.95	27.98
	GA (%)	4.3	3.3	6.47	8.6	3.52	15.17	7.11	11.96	5.48	10.65	5.2	11.45	3.94	7.59	6.26	7.61
	GCV (%)	5.7	4.4	8.65	8.4	5.18	10.13	7.64	9.89	7.13	8.74	4.77	16.16	5.2	6.32	6.98	6.58
	PCV (%)	16	13	19.2	17	16.14	13.52	17.44	16.46	20.65	16.28	14.19	25.66	13.77	11.62	16.03	12.45
	Mean	9	10	8	8	8	8	8	1	9	7	9	8	8	9	9	9
	Min.	8	8	6	6	7	6	6	6	6	7	12	6	6	7	5	7
	Max.	12	13	12	11	11	11	11	11	12	13	21	12	9	10	11	11
	CD at 0.05	3	2	3	2	3	1	3	2	3	4	3	3	2	2	2	2
	CV %	15	12	17	15	15	9	16	13	19	13	14	20	13	14	10	11
GPP	h^2 (%)	52	40	39.7	36	18.22	57.45	20.14	19.28	26.57	25.39	19.47	45.58	47.41	40.39	56.89	46.98
	GA (%)	19	15	17.2	12	6.53	19.78	7.63	7.03	8.19	7.94	6.3	20.13	19.6	15.18	23.26	16.32

	GCV (%)	13	11	13.2	10	7.42	12.67	8.25	7.77	7.73	7.63	6.92	14.76	13.81	11.59	14.96	11.55
	PCV (%)	18	18	21	17	17.39	16.72	18.39	17.69	14.99	15.15	15.7	21.87	20.06	18.23	19.84	16.85
	Mean	80	74	71	73	80	75	73	8	80	71	74	72	73	73	72	69
	Min.	61	59	52	57	61	59	56	0	65	50	52	53	57	58	54	54
	Max.	116	108	108	98	104	102	98	98	108	94	96	94	135	135	114	103
	CD at 0.05	20	20	23	19	25	16	24	23	21	20	20	23	21	20	19	17
	CV %	13	14	16	13	16	11	16	16	13	13	14	16	15	14	13	12
TW(g)	**h^2 (%)**	57	91	87.2	94	64.83	95.61	93.37	95.13	81.65	92.16	94.49	95.28	89.75	95.28	90.05	94.65
	GA (%)	9.4	14	14.4	22	16	21.61	21.46	21.69	19.61	21.44	22.16	35.47	21.12	22.07	21.35	21.74
	GCV (%)	6	7.1	7.49	11	9.64	10.72	10.7	10.79	10.53	10.84	11.06	18	10.81	10.97	10.91	10.84
	PCV (%)	7.9	7.5	8.01	11	11.98	10.97	11.15	11.06	11.66	11.29	11.38	18.44	11.41	11.24	11.5	11.14
	Mean	24.8	23.8	22.4	23.9	24.1	24.1	24.0	23.9	23.9	24.0	24.0	24.1	23.9	24.1	23.9	24.2
	Min.	21.6	20.6	19.2	17.0	17.2	17.2	17.1	0.0	16.6	16.6	16.7	16.9	16.3	16.6	16.4	16.6
	Max.	27.4	26.4	25.0	29.7	29.9	29.9	29.8	29.7	30.0	30.0	30.1	30.2	27.7	27.9	27.7	27.9
	CD at 0.05	**3**	**1**	**1**	**1**	**3**	**1**	**1**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**1**
	CV %	**5**	**2**	**3**	**3**	**7**	**2**	**3**	**2**	**5**	**3**	**3**	**4**	**4**	**2**	**4**	**3**
GYP Plant (g)	**h^2 (%)**	38	44	60	21	53.37	72.25	55.45	65.28	39.62	47.11	59.73	35.14	46.53	45.26	15.98	59.05
	GA (%)	13	15	27.2	8.3	30.46	37.25	31.19	39.26	21.93	23.91	37.9	22.89	20.82	19.51	7.47	27.7
	GCV (%)	10	10	16.9	8.7	19.29	20.31	19.35	22.43	15.16	15.12	21.81	17.57	14.81	14.07	9.06	17.48
	PCV (%)	17	16	21.8	19	26.4	23.9	25.99	27.77	24.09	22.03	28.21	29.65	21.71	20.92	22.67	22.75
	Mean	18	19	13	17	11	11	11	1	10	8	10	11	11	14	12	10
	Min.	8	8	5	8	4	5	4	4	4	4	4	4	8	5	8	7
	Max.	28	28	22	27	18	19	18	17	19	17	20	20	750	18	19	22
	CD at 0.05	**5**	**5**	**4**	**6**	**4**	**3**	**4**	**3**	**4**	**4**	**3**	**5**	**4**	**4**	**6**	**3**
	CV %	**13**	**12**	**14**	**17**	**18**	**13**	**17**	**16**	**19**	**16**	**18**	**24**	**16**	**15**	**21**	**15**
GYP Plot (g)	**h^2 (%)**	10	13	49.1	22	14.11	14.5	15.58	10.24	27.14	32.28	14.33	21.72	2.96	11.36	18.98	10.39
	GA (%)	1.5	2	22.2	4.6	9.29	7.55	3.31	2.24	92.64	39.07	45.13	71.57	0.35	1.87	2.25	1.3
	GCV (%)	2.3	2.7	15.4	4.7	4.07	3.9	4.06	3.39	11.25	3.96	2.88	9.29	0.99	2.68	2.5	1.96
	PCV (%)	7.2	7.5	22	10	10.83	10.24	10.3	10.6	21.59	6.98	7.61	19.94	5.78	7.96	5.75	6.08
	Mean	**227**	**216**	**219**	**208**	**222**	**211**	**208**	**208**	**225**	**214**	**211**	**211**	**216**	**205**	**202**	**202**
	Min.	**198**	**195**	**194**	**144**	**196**	**184**	**181**	**180**	**198**	**185**	**185**	**149**	**203**	**192**	**189**	**189**
	Max.	**301**	**493**	**299**	**399**	**255**	**244**	**241**	**241**	**252**	**241**	**238**	**238**	**242**	**231**	**228**	**228**
	CD at 0.05	**31**	**30**	**69**	**37**	**3**	**3**	**40**	**42**	**83**	**25**	**30**	**73**	**25**	**31**	**21**	**23**
	CV %	**7**	**7**	**16**	**9**	**2**	**2**	**9**	**10**	**18**	**17**	**7**	**18**	**6**	**7**	**5**	**6**

Table.3 Genetic parameters of 50 F_3progenies selected from F_2 population Cross- III (BG102/ Reshmi (F_1) Commercial hybrid based from different selection indices and grown under different crop ecology

Characters	Genetic parameters	I st method of selection (HY)				2nd method of selection (LY)				3rd method of selection (MTL)				4th method of selection (RPS)			
		I st Date		2nd Date		I st Date		2nd Date		I st Date		2nd Date		I st Date		2nd Date	
		DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP	DS	TP
DFF	h^2 (%)	87.00	69.17	69.17	44.48	69.63	69.63	71.68	69.63	99.82	99.87	99.76	99.92	99.62	99.80	99.43	99.84
	GA (%)	11.53	8.56	9.01	4.08	8.25	7.31	7.89	6.84	84.32	84.14	84.15	84.07	86.12	85.88	85.82	85.69
	GCV (%)	5.99	4.99	5.25	3.06	4.80	4.25	4.52	3.97	48.77	48.65	48.69	48.60	48.74	48.64	48.65	48.59
	PCV (%)	6.41	6.01	6.32	4.59	5.75	5.10	5.34	4.76	48.81	48.68	48.74	48.62	48.84	48.69	48.78	48.63
	Mean	81	91	87	97	77	87	83	93	81	91	86	97	79	89	84	95
	Min.	75	83	79	89	72	82	78	88	72	82	77	88	72	82	77	88
	Max.	90	100	95	106	87	97	93	103	89	99	95	105	89	99	95	105
	CD at 0.05	4	6	6	6	5	5	5	5	3	3	3	2	4	3	5	3
	CV %	2	3	4	3	3	3	3	3	2	2	2	1	3	2	4	2
PH (cm)	h^2 (%)	82.50	36.72	5.08	15.57	55.20	25.87	43.13	28.08	97.06	94.82	95.39	95.73	91.77	94.87	95.65	95.14
	GA (%)	18.16	7.19	1.23	2.80	15.45	5.91	13.08	6.64	85.96	82.82	85.22	83.61	77.95	79.44	74.72	79.69
	GCV (%)	12.51	5.75	2.65	3.44	10.09	5.64	9.66	6.07	50.41	49.14	50.42	49.37	49.93	49.15	50.46	49.30
	PCV (%)	13.77	9.50	11.77	8.73	13.58	11.09	14.71	11.47	51.17	50.47	51.62	50.47	52.12	50.46	51.59	50.54
	Mean	80	90	82	117	81	92	81	89	83	91	83	88	83	94	84	92
	Min.	51	72	67	104	54	68	54	65	59	69	60	66	55	81	81	78
	Max.	95	103	97	138	103	109	103	106	109	110	110	107	110	110	110	107
	CD at 0.05	15	14	19	20	15	18	18	17	12	18	16	16	21	18	15	17
	CV %	9	8	11	8	9	10	11	10	9	11	11	10	15	11	11	11
PPP	h^2 (%)	87.48	38.56	22.62	40.79	39.55	36.17	37.64	28.92	68.04	17.49	64.66	78.08	73.05	89.54	71.95	79.57
	GA (%)	12.04	14.26	8.38	20.74	9.65	12.08	15.78	12.40	70.67	19.70	60.39	73.94	71.63	81.14	67.60	77.24
	GCV (%)	13.75	11.35	8.90	9.99	10.02	12.76	12.35	11.55	45.43	27.83	44.93	47.58	46.39	49.58	46.38	47.84
	PCV (%)	14.70	18.28	18.71	15.64	15.94	21.22	20.13	21.47	55.08	66.55	55.87	53.85	54.28	52.39	54.68	53.62
	Mean	8	8	8	8	8	7	7	7	7	7	7	7	7	7	7	7
	Min.	1	5	3	6	3	6	4	4	5	5	4	5	5	5	5	5
	Max.	11	11	10	16	14	13	10	10	9	9	9	9	12	11	11	11
	CD at 0.05	2	2	3	3	2	2	2	2	4	7	4	3	4	2	3	3
	CV %	14	14	16	12	12	17	16	18	31	60	33	25	28	17	29	24
GPP	h^2 (%)	87.02	23.52	46.49	49.25	36.35	20.55	39.10	26.00	88.40	87.76	81.34	84.15	86.38	84.86	88.90	86.43
	GA (%)	19.67	7.37	18.65	20.49	12.57	6.53	13.25	8.08	83.88	78.47	77.12	76.02	82.92	75.73	81.75	75.68

	GCV (%)	16.16	7.37	13.27	14.16	10.12	6.99	10.28	7.69	51.55	48.40	49.41	47.89	51.23	47.99	50.64	48.24
	PCV (%)	17.33	15.20	19.47	20.19	16.78	15.42	16.44	15.08	54.83	51.66	54.78	52.20	55.12	52.10	53.70	51.89
	Mean	81	80	82	88	82	78	81	78	85	80	85	80	85	81	86	81
	Min.	56	64	57	18	40	63	60	63	60	64	61	63	42	66	58	67
	Max.	107	101	108	118	140	116	101	116	129	103	130	102	114	95	117	95
	CD at 0.05	10	9	9	2	14	10	9	9	8	8	10	11	24	16	24	15
	CV %	6	5	5	1	9	6	6	6	6	6	7	8	14	10	14	9
TW(g)	**h^2 (%)**	97.08	96.98	96.87	96.42	97.01	90.10	96.75	96.76	99.77	99.44	99.63	99.70	99.40	99.76	99.80	99.70
	GA (%)	29.69	26.36	28.94	28.31	26.43	25.27	27.82	27.53	87.39	38.61	41.98	89.67	86.54	84.11	87.03	89.63
	GCV (%)	14.62	12.99	14.26	13.01	13.02	13.04	13.72	13.29	50.55	56.11	59.47	50.51	50.50	50.54	50.53	50.51
	PCV (%)	14.84	13.19	14.49	13.25	13.21	13.74	13.95	13.51	50.60	56.26	59.58	50.58	50.65	50.60	50.58	50.58
	Mean	25	26	25	20	26	25	24	24	25	25	26	25	26	26	26	25
	Min.	17	18	17	14	18	17	17	18	21	20	21	20	20	20	20	19
	Max.	31	31	31	26	32	31	31	31	31	30	31	32	31	32	32	33
	CD at 0.05	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1
	CV %	3	2	3	3	2	4	3	2	2	4	4	3	4	2	2	3
GYP Plant (g)	**h^2 (%)**	88.09	42.27	41.66	35.03	31.53	10.07	43.94	54.60	83.49	76.35	76.97	86.73	84.91	83.31	85.75	77.83
	GA (%)	12.57	17.21	19.26	16.77	14.65	23.00	21.48	23.23	98.27	79.08	84.34	84.61	90.92	82.10	93.59	93.55
	GCV (%)	17.04	12.84	14.48	13.59	12.65	3.80	15.71	18.21	62.09	52.28	55.52	60.32	62.43	53.30	57.15	58.96
	PCV (%)	18.15	19.75	22.43	22.96	22.53	11.97	23.71	24.65	67.95	59.83	63.28	64.77	67.75	58.40	61.71	66.83
	Mean	19	18	17	18	11	10	10	11	10	10	10	10	11	10	10	9
	Min.	12	13	9	9	6	6	5	3	2	5	5	3	1	3	2	2
	Max.	31	28	28	26	15	18	15	19	16	14	15	16	17	19	17	15
	CD at 0.05	7	5	196	7	4	21	4	3	5	5	5	4	4	4	4	5
	CV %	19	15	16	19	19	6	18	17	28	29	30	24	26	24	23	31
GYP Plot (g)	**h^2 (%)**	77.20	55.28	44.53	51.05	65.51	74.54	70.73	75.07	88.67	93.86	89.20	90.88	91.10	92.70	91.85	92.94
	GA (%)	16.18	25.19	19.87	22.65	33.93	52.39	39.47	52.68	79.76	76.57	63.51	72.61	85.34	95.18	87.64	89.64
	GCV (%)	16.43	16.44	14.45	15.38	20.35	29.45	22.78	29.51	63.18	69.53	66.39	74.32	63.64	69.30	66.67	74.76
	PCV (%)	18.70	22.12	21.66	21.53	25.14	34.11	27.08	34.06	67.10	71.76	70.29	77.96	66.67	71.98	69.57	77.54
	Mean	631	587	604	218	323	268	295	268	292	256	264	236	359	311	332	328
	Min.	342	294	315	151	120	34	93	34	128	40	100	40	59	53	31	61
	Max.	988	982	960	319	480	444	452	444	469	496	441	458	658	552	630	655
	CD at 0.05	113	104	113	66	57	52	51	92	111	77	103	94	98	84	88	82
	CV %	9	9	9	15	9	10	9	17	23	18	23	24	20	19	20	21

Table.4 Estimates of standardized selection differential, standardized selection response and realized heritability for different traits from two methods as well as two date of sowing based on different methods of selection of Cross- I (BG102/BPT5204)

Methods of selection and selection intensity (5%)	Population mean	No. of selected lines	Mean of selected parent	Standardized selection differential (S /σ p)	Progeny mean				Standardized selection response (R /σp)				Average standardized selection response	Realized heritability (R/S)				Average Realized heritability
					I st Date		2nd Date		I st Date		2nd Date			I st Date		2nd Date		
					DS	TP	DS	TP	DS	TP	DS	TP		DS	TP	DS	TP	
Based on HY		50																
PH (cm)	116.15		122.12	0.46	122.01	121.06	121.79	121.70	0.45	0.38	0.43	0.43	0.42	0.98	0.82	0.94	0.93	0.92
PPP	8.08		12.32	1.41	12.07	10.63	11.00	12.29	1.33	0.85	0.97	1.40	1.14	0.94	0.60	0.69	0.99	0.81
GPP	78.48		109.48	1.14	80.95	103.34	99.22	88.37	0.09	0.92	0.76	0.36	0.53	0.08	0.80	0.67	0.32	0.47
GYP Plant (g)	10.12		25.38	2.68	24.90	24.52	20.25	17.49	2.60	2.53	1.78	1.30	2.05	0.97	0.94	0.66	0.48	0.76
Based on LY		50																
PH (cm)	116.15		122.34	0.48	122.30	121.43	122.09	122.20	0.47	0.41	0.46	0.46	0.45	0.99	0.85	0.96	0.98	0.95
PPP	8.07		10.06	0.66	9.74	9.94	10.00	9.74	0.55	0.62	0.64	0.55	0.59	0.84	0.94	0.97	0.84	0.90
GPP	78.48		89.76	0.42	88.06	89.30	89.59	89.00	0.35	0.40	0.41	0.39	0.39	0.85	0.96	0.98	0.93	0.93
GYP Plant (g)	10.12		16.43	1.11	15.90	15.50	15.72	15.90	1.02	0.95	0.98	1.02	0.99	0.92	0.85	0.89	0.92	0.90
Based on MTL		48																
PH (cm)	116.15		101.92	-1.09	114.72	115.37	115.62	115.33	-0.11	-0.06	-0.04	-0.06	-0.07	0.10	0.05	0.04	0.06	0.06
PPP	8.07		9.08	0.34	9.00	8.63	8.78	8.45	0.31	0.19	0.24	0.13	0.22	0.92	0.55	0.70	0.38	0.64
GPP	78.48		87.85	0.35	85.19	85.96	87.80	84.48	0.25	0.28	0.34	0.22	0.27	0.72	0.80	0.99	0.64	0.79
GYP Plant (g)	10.12		10.76	0.11	10.72	10.43	10.69	10.63	0.11	0.05	0.10	0.09	0.09	0.94	0.48	0.89	0.79	0.78
Based on RPS		50																
PH (cm)	116.15		124.72	0.66	120.66	122.90	123.96	123.88	0.35	0.52	0.60	0.59	0.52	0.53	0.79	0.91	0.90	0.78
PPP	8.07		9.72	0.55	9.65	8.83	9.28	9.36	0.52	0.25	0.40	0.43	0.40	0.96	0.46	0.74	0.78	0.74
GPP	78.48		90.28	0.43	88.74	82.61	88.56	89.03	0.38	0.15	0.37	0.39	0.32	0.87	0.35	0.85	0.89	0.74
GYP Plant (g)	10.12		16.08	1.05	15.88	15.58	14.82	14.82	1.01	0.96	0.83	0.83	0.91	0.97	0.92	0.79	0.79	0.87

Table.5 Estimates of Standardized selection differential, standardized selection response and realized heritability for different traits from two methods as well as two date of sowing based on different methods of selection of Cross- II (BG102/Naveen)

Methods of selection and selection intensity (5%)	Population mean	No. of selected lines	Mean of selected parent	Standardized selection differential (S/σ p)	Progeny mean				Standardized selection response (R/σp)				Average standardized selection response	Realized heritability (R/S)				Average Realized heritability
					I st Date		2nd Date		I st Date		2nd Date			I st Date		2nd Date		
					DS	TP	DS	TP	DS	TP	DS	TP		DS	TP	DS	TP	
Based on HY		50																
PH (cm)	115.36		117.52	77.88	117.10	116.70	115.90	117.00	77.45	77.06	76.26	77.36	77.03	0.99	0.99	0.98	0.99	0.99
PPP	7.57		9.98	7.14	9.29	9.74	7.86	7.96	6.46	6.91	5.02	5.12	5.88	0.90	0.97	0.70	0.72	0.82
GPP	69.6		80.58	67.47	80.23	74.27	71.01	73.38	67.12	61.16	57.90	60.28	61.62	0.99	0.91	0.86	0.89	0.91
GYP Plant (g)	10.01		23.06	21.17	18.31	18.62	12.97	17.38	16.42	16.74	11.08	15.50	14.94	0.78	0.79	0.52	0.73	0.71
Based on LY		50																
PH (cm)	115.36		118.20	78.56	115.00	113.66	115.60	117.00	75.36	74.02	75.96	77.36	75.68	0.96	0.94	0.97	0.98	0.96
PPP	7.57		8.32	5.48	8.18	7.92	8.16	7.96	5.34	5.09	5.32	5.12	5.22	0.97	0.93	0.97	0.93	0.95
GPP	69.6		81.82	68.71	80.00	74.97	72.59	73.30	66.90	61.87	59.48	60.19	62.11	0.97	0.90	0.87	0.88	0.91
GYP Plant (g)	10.01		14.17	12.28	10.82	11.30	10.89	9.89	8.94	9.42	9.00	8.01	8.84	0.73	0.77	0.73	0.65	0.72
Based on MTL		49																
PH (cm)	115.36		105.69	66.05	103.50	91.76	92.94	92.05	63.86	52.12	53.29	52.41	55.42	0.97	0.79	0.81	0.79	0.84
PPP	7.57		9.14	6.31	8.58	7.44	8.82	8.30	5.75	4.60	5.98	5.46	5.45	0.91	0.73	0.95	0.87	0.87
GPP	69.6		90.61	77.50	79.79	74.33	70.61	71.53	66.68	61.22	57.51	58.43	60.96	0.86	0.79	0.74	0.75	0.79
GYP Plant (g)	10.01		11.51	9.63	9.74	10.17	7.91	10.54	7.85	8.28	6.03	8.65	7.70	0.82	0.86	0.63	0.90	0.80
Based on RPS		50																
PH (cm)	115.36		115.76	76.12	115.37	113.58	115.06	114.48	75.72	73.94	75.42	74.84	74.98	0.99	0.97	0.99	0.98	0.98
PPP	7.57		8.76	5.92	8.05	8.62	8.60	9.11	5.22	5.78	5.77	6.28	5.76	0.88	0.98	0.97	1.06	0.97
GPP	69.6		73.42	60.31	72.90	72.26	72.61	69.32	59.79	59.15	59.50	56.21	58.66	0.99	0.98	0.99	0.93	0.97
GYP Plant (g)	10.01		14.14	12.25	11.35	11.83	14.03	10.40	9.47	9.95	12.15	8.51	10.02	0.77	0.81	0.99	0.69	0.82

Table.6 Estimates of Standardized selection differential, standardized selection response and realized heritability for different traits from two methods as well as two Date of sowing based on different methods of selection of Cross- III(BG102/ Reshmi (F_1)) Commercial Pvt. hybrid

Methods of selection and selection intensity (5%)	Population mean	No. of selected lines	Mean of selected parent	Standardized selection differential (S/σ p)	Progeny mean				standardized selection response (R/σp)				Average standardized selection response	Realized heritability (R/S)				Average Realized heritability
					I st Date of sowing		2nd Date of sowing		I st Date of sowing		2nd Date of sowing			I st Date of sowing		2nd Date of sowing		
					DS	TP	DS	TP	DS	TP	DS	TP		DS	TP	DS	TP	
Based on HY																		
PH (cm)	115	50	119.1	108.85	79.62	89.8	82.4	117.2	69.35	79.5	72.13	106.93	81.99	0.64	0.73	0.66	0.98	0.75
PPP	6.82		9	6.47	8.33	8.19	7.86	8.38	5.8	5.66	5.33	5.85	5.66	0.90	0.87	0.82	0.90	0.87
GPP	80.2		95.6	92.64	80.61	80.42	81.8	88.36	77.65	77.5	78.82	85.4	79.83	0.84	0.84	0.85	0.92	0.86
GYP Plant (g)	25.3		19.8	17.46	19.17	17.56	16.8	17.61	16.83	15.2	14.45	15.27	15.44	0.96	0.87	0.83	0.87	0.88
Based on LY		50																
PH (cm)	115		115.1	104.81	81.33	92.48	81.2	89.45	71.06	82.2	70.97	79.18	75.86	0.68	0.78	0.68	0.76	0.73
PPP	6.82		8.6	6.07	8.2	7	7.07	6.85	5.67	4.47	4.54	4.32	4.75	0.93	0.74	0.75	0.71	0.78
GPP	80.2		85.82	82.86	82.04	78.47	80.7	78.47	79.08	75.5	77.77	75.51	76.97	0.95	0.91	0.94	0.91	0.93
GYP Plant (g)	25.3		11.66	9.32	11.04	9.98	10.2	11.31	8.7	7.64	7.87	8.97	8.30	0.93	0.82	0.84	0.96	0.89
Based on MTL		42																
PH (cm)	115		101.7	91.4	83.38	91.41	83.4	88.48	73.11	81.1	73.14	78.21	76.40	0.80	0.89	0.8	0.86	0.84
PPP	6.82		8	5.47	7.45	7.29	7.03	7.14	4.92	4.76	4.5	4.61	4.70	0.90	0.87	0.82	0.84	0.86
GPP	80.2		103.7	100.75	85.09	80.22	85.1	79.5	82.13	77.3	82.16	76.54	79.52	0.82	0.77	0.82	0.76	0.79
GYP Plant (g)	25.3		10.53	8.19	9.92	9.87	10.4	10.25	7.58	7.53	8.1	7.91	7.78	0.93	0.92	0.99	0.97	0.95
Based RPS		50																
PH (cm)	115		119.7	109.45	83.38	91.41	83.4	88.48	73.11	81.1	73.14	78.21	76.40	0.67	0.74	0.67	0.71	0.7
PPP	6.82		7.56	5.03	7.29	7.07	6.83	6.9	4.76	4.54	4.3	4.37	4.49	0.95	0.90	0.86	0.87	0.9
GPP	80.2		99.34	96.38	84.56	80.97	86.1	81.3	81.6	78	83.14	78.34	80.27	0.85	0.81	0.86	0.81	0.83
GYP Plant (g)	25.3		11.32	8.98	10.82	10.27	10.3	8.73	8.48	7.93	7.98	6.39	7.70	0.94	0.88	0.89	0.71	0.86

DFF = Days to 50 % Flowering, PH = Plant Height, PPP = Panicle per Plant, PL = Panicle Length, GPP = Grains per Panicle, GYP plant = Grain yield per plant, GYP plot = Grain yield per plot, HY = High Yielder, LY = Low yielder, MTL = Multi trait limit, RPS = Random plant selection, DS = Direct seeding, TP = Transplanting, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation and GA = Genetic Advance.

While, Twin all methods and both date of planting indicating the preponderance of additive gene action was exhibited high h^2 coupled with high GA as per cent of mean earlier finding reported by Lokprakash *et al.*, (1992) and Lingaiah (2015), Singh *et al.*, (2013) and Tuhina *et al.*, (2015). The high heritable characters should be fairly easy and could be used as a selection criterion for future hybridisation programme. This is because there would be close correspondence between the genotype and phenotype due to relatively smaller contribution of the environment to the phenotype. Heritability estimates along with genetic gain are normally more helpful in predicting the gain under selection rather than only heritability estimates (Johanson *et al.,* 1955).

Cross-I had exhibited maximum average selection response for all the studied traits in LY followed by HY and RPS selection method. It might be probable that delaying selection reduces the frequency of high yielding genotypes resulting a greater frequency of low yielding genotypes. Cross – II and Cross – III were obtained highest average selection response for all studied traits in HY followed by LY selection method are given in the (Table 4, 5 and 6). Although the results indicate that the improvement obtained by selecting in late generation is just as effective as in early generations, a strong argument for selecting for yield in early generations is to permit testing in many sites and years at an early stage. The results of selection for low yield supported by earlier findings Shebeshki L. H. 1967, Whan *et al.*, (1982), Verma and Mani (2000), and Ahmad *et al.*, (2017).

Cross –II exhibited highest standardized selection differential for all studied traits based on HY followed by LY selection method while in Cross –II as well as Cross – III in HY followed by RPS methods. It might be due to the frequency of best genotypes rapidly decreases with advancing generation similar finding earlier reported by Shebeshki L. H. 1967, Verma and Mani (2000), and Ahmad *et al.*, (2017).

In Cross –I; Selection based on HY, high realized h^2 was observed for all characters under different methods of planting in both dates of sowing except in 2^{nd} date of TP for traits GPP and GYP plant it might be due to environmental effects. High level of realized h^2 was also recorded under RPS for all the traits in different methods of planting on different dates of sowing barring for the trait PH under DS condition while for PPP and GPP under TP condition in I^{st} date of planting which were comprising low realized h^2 it might be due to the influence of environment, whereas under MTL for PH and PPP low h^2were recorded in different method of planting as well as on different date of sowing except in DS condition in 2^{nd} date of sowing for the traits PPP, while high realized h^2 was recorded for traits GPP and GYP plant in different method of planting on both dates of sowing except for TP on I^{st} of sowing of GPP whereas Cross –II and Cross –III were obtained high realised h^2 for all studied traits in different methods of planting on both dates of sowing suggesting that early generation of selection may be effective. This finding is corroborated with Verma and Mani (2000), Vir and Singh (2005) and Kumar *et al.*, (2009) and Ahmad *et al.*, (2017).

In the present investigation it can be concluded that among different methods of selection HY followed by LY selection method may be effective in early segregating generation for Cross – II as well as Cross – III whereas for Cross – I; LY followed by HY selection method may be more effective. It might be probable that delaying selection reduces the frequency of high yielding genotypes resulting in a greater frequency of

low yielding genotypes. Although the results indicate that the improvement obtained by selecting in late generation is just as effective as in early generations, a strong argument for selecting for yield in early generations is to permit testing in many sites and years at an early stage. However, on the other hand judicious selection causes increase in mean of the population for certain traits. Since, breeder is concerned with the enhancing of means for the traits; he may get an improved population at the onset of homozygosity at F_8 and onward stages.

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